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An Assessment of the GoldenEye-50 Operator Control Unit

by Catherine N. Jacobson and Cheryl A. Burns

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14. ABSTRACT

The GoldenEye-50, developed by Aurora Flight Sciences, was selected by the Defense Advanced Research Projects Agency as one of multiple candidates to provide the basic platform for the Organic Air Vehicle II program for expected integration into the U.S. Army's Future Combat System program. The GoldenEye-50 is a transportable (approximately 18 lb) unmanned aerial vehicle (UAV) with vertical take-off and landing capability. It is designed to carry a payload to support reconnaissance and chemical detection missions and can transform from a hover-and-stare mode to wing-borne flight as needed. In support of the Human-Robot Interaction Army Technology Objective, an assessment of the operator control unit (OCU) was conducted during a technical demonstration of the GoldenEye-50 held at Fort Knox, Kentucky, from 9 to 12 May 2005. The authors' primary objective was to reveal human factors engineering issues associated with the design of the OCU interface and to learn the tasks of a UAV operator, particularly with multi-mode flight capability of vertical and horizontal flight. From the observational data, potential issues and recommendations for the final OCU interface design accepted by the Army are presented.

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Contents

List of Figures

List of Tables

1. Introduction

A technical demonstration of the GoldenEye-50 developed by Aurora Flight Sciences was conducted at Fort Knox, Kentucky, from 9 to 12 May 2005. The GoldenEye-50 was selected by the Defense Advanced Research Projects Agency as one of several candidates to provide the basic platform for the Organic Air Vehicle II program for expected integration into the U.S. Army's Future Combat System program. It is a prototype unmanned aerial vehicle (UAV) capable of wing-borne flight, vertical take-off and landing (VTOL) and hover-and-stare capabilities. With a payload weight of approximately 2 pounds, the UAV is designed to be equipped for missions involving both surveillance and chemical detection. For the demonstration at Fort Knox, however, the payload was limited to a video camera on a fixed mount for live video feed. The GoldenEye-50 weighs approximately 18 pounds, stands almost 28 inches tall with a wing span approaching 4.5 feet. Its engine is housed in a ducted fan configuration whereby the propeller is enclosed in the body of the aircraft. Aurora Flight Sciences' reported cruise speed for this UAV is a little over 62 miles per hour with a maximum speed of just below 174 miles per hour with a cruise time of 1 hour.

The operator control unit (OCU) used to fly the GoldenEye-50 during the Fort Knox demonstration was an engineering interface co-developed by Aurora Flight Sciences and Athena Technologies. The OCU used at Fort Knox was not intended to be the final design for use by the target audience (i.e., U.S. Army Soldiers); rather, it was designed for Aurora Flight Sciences personnel to fly the UAV during flight tests and to collect engineering data. The U.S. Army Research Laboratory's Human Research and Engineering Directorate, Fort Knox field element, attended the demonstration of the GoldenEye-50 in order to observe the OCU interface used to fly the UAV. Although not anticipated to be the final OCU used with this UAV it was determined that an evaluation of the engineering interface would be helpful in identifying issues related to the human factors engineering (HFE) design of OCUs in general and specifically with regard to the capabilities residing in the GoldenEye-50 (i.e., VTOL and wing-borne flight). The primary objective was to reveal HFE issues associated with the design of the OCU interface and to learn the tasks of a UAV operator, particularly with multi-mode flight capability of vertical and horizontal flight. From the observational data, potential issues and recommendations for the final OCU interface design accepted by the Army are presented. The following paragraphs include (a) a summary of the mission schedules, (b) a description of the OCU, (c) a discussion of limitations of observations, (d) a discussion of HFE observations and noted UAV operator tasks. Observations focused on HFE considerations of the OCU, including such issues as operator workload, operator required skills and abilities, situation awareness, information display, and OCU functionality.

Figure 1. GoldenEye-50.

2.   Summary of Flight Missions

Table 1 summarizes the flight missions performed by GoldenEye–50 from 9 to 12 May. The following bulleted list describes the basic activities of the UAV for the different flight mission types:

- Cardinal Heading: Fly a box pattern due north, east, south, and west.

- Route Reconnaissance: Follow a range road, pause the UAV's scripted mission scenario to stop and hover while using payload to identify targets, resume mission scenario.

- Area Reconnaissance: Fly from waypoint to waypoint (pre-entered), pause the UAV's scripted mission scenario to stop and hover while using payload to identify targets, resume mission scenario.

Table 1. Flight mission descriptions

Date	Flight Mission Description
09 May	Initial flight (global positioning system sensitivity caused flight to be terminated early)
10 May	Flew cardinal heading box and observed various waypoints en route (Yano Range)
	Flew to bridge on Yano range and observed bridge and surrounding area (Yano Range)
	Performed route reconnaissance of range roads and paused to observe moving targets, and returned to take-off launch point (Yano Range)
11 May	Performed area reconnaissance flight, paused 3 times to observe various waypoints (Godman Airfield)
	Performed area reconnaissance flight, paused 3 times to observe various waypoints (Godman Airfield)
12 May	Performed area reconnaissance flight, paused 2 times to observe various waypoints (Godman Airfield)

3. Description of OCU

The OCU used for the GoldenEye-50 demonstration at Fort Knox was an engineering prototype developed specifically for use by Aurora Flight Sciences personnel and was not intended for use by Army personnel. Figure 2 illustrates the main screen of Aurora Flight Sciences' OCU interface. The system is run from a laptop computer and is activated via a touch screen with a mix of function buttons, data fields, and a map display. The situation display uses the entire screen of the standard sized laptop computer. The map display has zoom capabilities via a drag-and-drop method; dragging the stylus across an area of interest will activate the zoom feature over that area. The function buttons appear to be designed for scripted flights with a high level of control over the UAV. For example, during take-off, the operator pushes the "take-off" button and the UAV performs that function without any further input. When the mission script is paused, the operator uses function buttons to manually control the UAV, although manual control is limited to screen taps that move the aircraft a predetermined amount. For example, one tap of a button will result in the UAV rotating 3 degrees. Furthermore, manual control of the UAV's movements is limited to the hover mode; the operator cannot manually fly the UAV in a wing-borne flight mode. Figure 3 illustrates a pop-up screen that displays initial settings where the controller can determine the sensitivity of navigation buttons. The data displayed are technical and appear to only provide real-time feedback about the aircraft's flight control systems. No warning displays are available, and information about pre-determined parameters for safe flight (e.g., altitude, pitch angle, etc.) are not provided; the operator must possess an awareness of parameters that must be maintained to keep the UAV in safe flight.
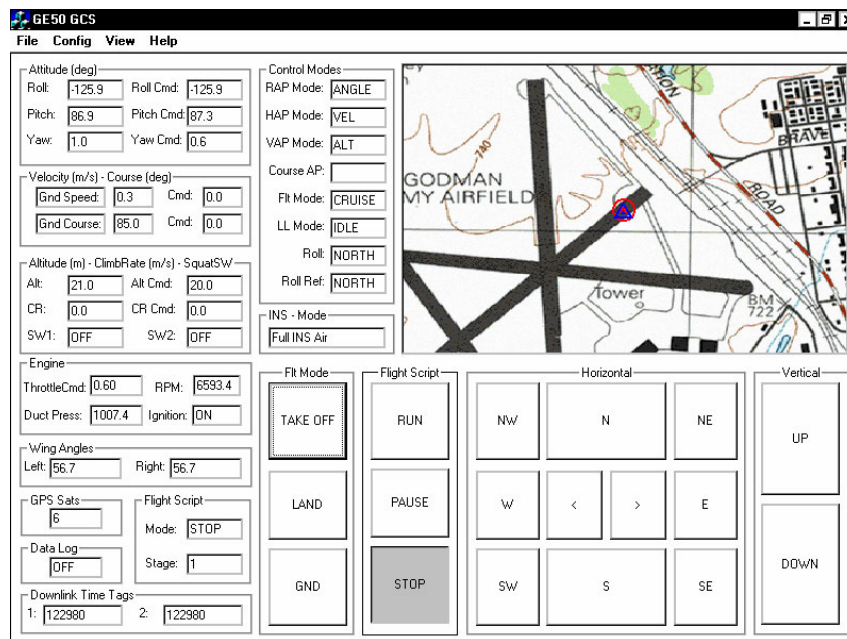

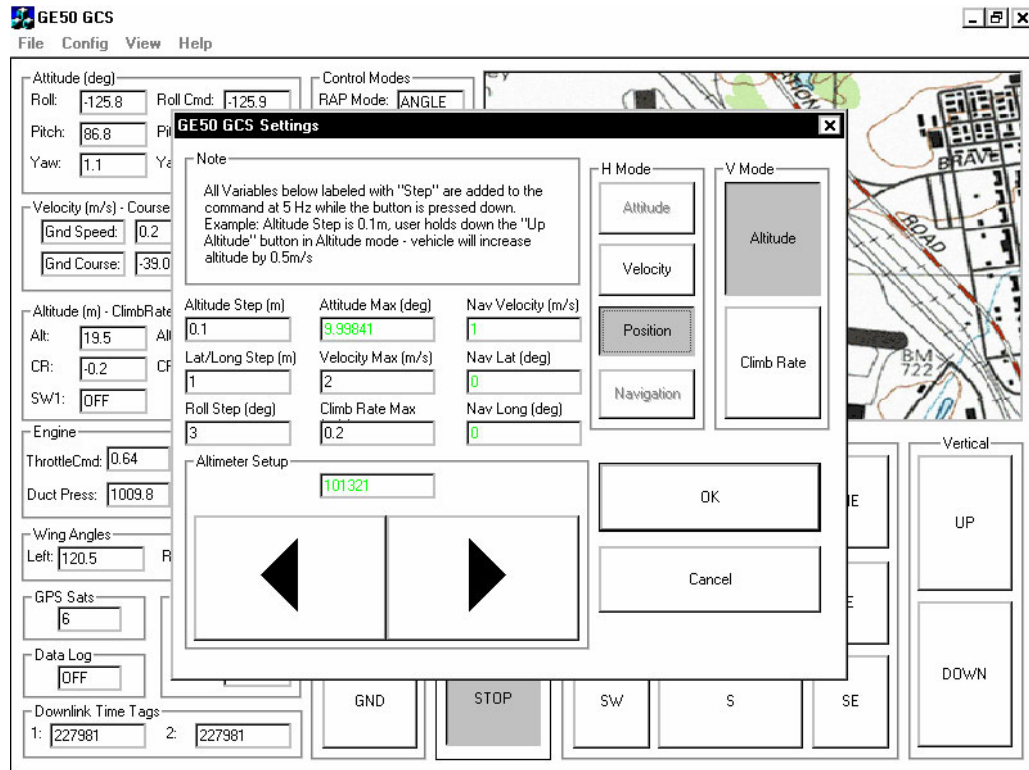Figure 2. Main screen for Aurora Flight Sciences' OCU.

Figure 3. Initial settings pop-up menu on Aurora Flight Sciences' OCU.

4. Limitations of HFE Observations

HFE observations made during the technical demonstration of the GoldenEye-50 were limited because the UAV used for this event was an engineering prototype. Because the UAV demonstrated at Fort Knox was only in a prototype developmental stage, it lacked many features and capabilities that could significantly impact HFE-related issues for the operator in terms of the UAV itself and the accompanying OCU. First, the payload was not fully developed; the camera was not mounted on a gimbal for panning and zooming, and no picture-taking or video-capturing functionalities were available. Because the payload was not fully developed, the workload assigned to a UAV operator for this demonstration could not be thoroughly evaluated since workload could increase with increased payload functionality but likewise, could decrease as payload becomes easier to operate. For this demonstration, the only way to operate the camera for panning and zooming was to manipulate the body (e.g., pitch and roll) of the UAV. Second, the ability to plan and edit routes was unavailable to the operator because scripted mission plans were downloaded to the GoldenEye-50 in advance and could not be altered in flight. The lack of such functionality does not allow a thorough HFE evaluation (e.g., operator workload, display

design, etc.). Some observations, however, did contribute to our understanding of potential workload issues associated with controlling the UAV.

In addition to the early developmental stage of the UAV used during this demonstration, the OCU was an engineering prototype and was not designed for use by Army personnel of a grade and military occupational specialty designated to control UAVs in an operational environment. For example, the type of information displayed and functionalities residing in the OCU appear to be designed for Aurora Flight Sciences personnel to man the GoldenEye-50 so that the UAV is controlled at a high level; the UAV was pre-loaded with scripted flights and only allowed the operator to pause scripted missions to manipulate the UAV to work the payload. Keys were available to launch, land, run script, and pause script as these were the primary input to the UAV from the operator. During script pauses, the operator was able to control movement of the UAV but was not able to manually launch or land the system other than push buttons for *take-off* and *land*. Information about HFE issues gleaned from observation of the OCU operator must be viewed in light of the OCU as an engineering prototype developed for use by Aurora Flight Sciences personnel only and should be considered as recommendations for design of the Army's OCU(s) rather than as an assessment of the OCU.

Finally, the demonstration did not involve U.S. Army Soldiers since it was conducted solely by Aurora Flight Sciences personnel. The OCU was manned primarily by one civilian employee from Aurora Flight Sciences with a small handful of engineers standing nearby with associated tasks. Because of these circumstances, feedback and observations of the OCU were limited to one operator not associated with the Army and with no experience as an Army Soldier. Observations were still deemed useful since much of the information extrapolated from the demonstration could be applied to Army personnel as OCU operators.

5. Summary of HFE Findings and Observations

5.1. Feedback on Diagnostics and Safe Flight Parameters

Events that occurred during the first flight mission executed by Aurora illustrated the need for the OCU operator to be supplied with feedback from the UAV in terms of its "health" (i.e., fuel and oil levels, engine temperature) or problems with its avionics system, communication with satellites, control surfaces, and payload problems. The first flight mission performed during the demonstration was aborted because of an interruption in satellite availability. The pre-programmed script called for the UAV to automatically switch to land mode when insufficient satellite coverage was detected. This portion of the script was not known to the OCU operator and furthermore, no warnings on the OCU screen indicated that satellite coverage was insufficient per the UAV's criteria for continuing the scripted flight. The OCU operator was

unable to determine why the UAV *unexpectedly* performed an automatic land. While the OCU did provide the operator with information about how many satellites were available and how they were clustered in space, the operator apparently was not aware of how many (and placement) of the satellites were needed for the UAV to continue its scripted mission. Furthermore, the automatic land sequence, given a lack of proper satellite coverage that was embedded in the scripted flight mission, added to the operator's poor situation awareness at the time.

The operator was unable to determine the status of power supplied to the avionics; during initial start-up, a member of the Aurora team (similar to a ground crew member) had to give verbal notice to the operator that avionics power was on from his position standing next to the UAV. Furthermore, during start-up for one of the scenarios, the Aurora ground crew member alerted the operator that the engine did not sound right and directed the operator to abort the mission until further inspection of the engine was performed. It was determined that the engine had blown a rod. Without input from the aural indications picked up by the Aurora ground crew member, the operator had no indication that an engine problem existed. The last report observed was that engine revolutions per minute (rpm) appeared normal. Radio conversation between the ground crew member and the operator linked the operator to the potential problem with the GoldenEye's engine.

When asked what features would be helpful if added to the OCU, the operator indicated that visual warnings (e.g., red and yellow lights) indicating when the UAV is out of the safe flight parameters during a mission (e.g., extreme pitch) would be useful. The operator of this UAV usually did not have direct control over flying the aircraft; rather, he continually monitored the system (e.g., altitude, engine rpm, pitch, roll, etc.) to ensure that it was engaged in safe flight. Only when scripted missions were paused did the operator exert direct control over the UAV. Regardless of whether an operator is exerting direct control over a UAV or if that person is simply monitoring a pre-set flight mission, an alert system built into the OCU may reduce workload, increase situation awareness, and reduce instances of operator error or accidents attributable to system malfunctions within the UAV.

5.2   Frequently Accessed Information

In monitoring the UAV, the operator continually referenced certain information. While the need for information will vary, depending on the level of operator control, the following information was frequently referenced for the operator when controlling the GoldenEye-50 during scripted runs and during pauses in the script: engine rpm, percentage of engine power used, velocity, ground speed, altitude, roll, pitch, yaw, wing position, and flight mode. The type of information needed and the frequency of reference by the operator are a function of several factors including the level of control assigned to the operator, the flight mission tasks, and the mode of flight. In this demonstration, the operator was generally limited to a high level of control so that his tasks during flight were primarily to monitor the aircraft for safe flight. While future UAV designs

may allow more operator control, it is important to consider the information needed by operators during all levels of control.

5.3   Map Zoom

The operator used the zoom feature of the area map extensively. When approaching waypoints, the operator quickly zoomed to increase the accuracy of the UAV's position relative to the waypoint. Once the UAV approached the waypoint, the workload of the operator increased as he paused the script and assumed control of the UAV in order to manipulate the payload. The map zoom feature was frequently and quickly used by the operator, which suggests that a design that supports quick zooming capability (i.e., fewest possible mouse clicks, pen taps, or key strokes) is important for keeping the operator on task in a timely manner.

5.4   OCU Operator Tasks

For the GoldenEye-50 demonstration, the tasks of the OCU operator were primarily monitoring the UAV for safe flight parameters and mentally cross checking the real-time displays of data with what he knew to be safe flight parameters for the UAV. Other than performing initial start-up checklists, the OCU operator primarily functioned as a monitor. Because no warnings or alerts resided in the OCU, the operator spent a considerable amount of time monitoring, which kept him from allotting time during flight to monitor or reference the payload. During pauses in the script when the operator took control of the UAV, the workload for maneuvering the UAV and continuing to monitor the flight parameters was so high that a second individual managed the payload and directed the operator when and how much to rotate the UAV until the script was resumed. While a complete assessment of operator tasks was not possible because the GoldenEye-50 and its OCU lacked much functionality, it is apparent that workload is a key factor in how many and what kinds of tasks a UAV operator can perform.

Robot-to-operator ratio (feasibility of one per man, one robot). The ability to achieve a one-to-one ratio for operating a UAV is governed by operator workload and logistics during start-up. From the demonstration of the GoldenEye-50, it appears that at least three people were required to complete the UAV missions:

- Ground crew member: Performed the engine start-up, turned on avionics and ignition switch, listened for signs of engine malfunction, unsecured the UAV from its tie-down straps just before take-off.

- Operator: Handled all aspects of monitoring and managing the UAV during flight; executed the different flight modes, take-off and landing.

- Commander/Payload operator: Provided the operator with direction about when to start and stop the script pauses, commanded the operator in navigation during paused flight

scripts, monitored the visual feed from the payload, and commanded the operator about directions to turn, based on payload information.

5.5 Pre-flight Status and Pre-flight Start-up Checklists

During this demonstration, the operator performed two checklists before initiating take-off of the UAV. A pre-flight status check was performed for assurances such as avionics powered on the UAV, ignition on the UAV, and completion of engine throttle runs. A pre-flight start-up checklist was also performed to ensure that certain parameters (e.g., maximum climbing rate, degrees of roll of the UAV per operator input) are correctly entered into the OCU (Aurora Flight Sciences refers to this as the ground control station). As these procedures may be an integral part of sending a UAV on a mission, it is important that any pre-flight checklists be incorporated into the final OCU design.

5.6 Ability to Transition From Different Modes of Flight (vertical to horizontal flight path)

Because of the high level of control for the GoldenEye-50, the ability to transition from different flight modes was not addressed. Because the operator did not directly manipulate the control surfaces of the UAV, the transition from vertical flight to horizontal flight was transparent to the operator. The control input seen on the OCU interface in figure 2 is used when the UAV is in hover mode. Because the operator for the GoldenEye-50 is not able to control the UAV when it is in wing-borne flight mode, it was not possible to assess the interface for ease of transition from one flight mode to another.

5.7 Touch screen

The operator noted that the touch screen leaves him vulnerable to accidental or inadvertent input to the OCU. Several times, he braced his hand on a portion of the OCU to maintain a safe distance for the touch pad and indicated that at one time, he came close to making an accidental input on the screen. The buttons close to the bottom of the screen appeared to be the most vulnerable to accidental and inadvertent input. These buttons also appeared to be similar to "hot keys" in that one press would result in stopping the mission script or landing the aircraft. It is important that consequences of accidents such as inadvertent key strokes or pen taps be minimized when possible; placing the location of action buttons away from areas that are most likely to incur accidental input or reducing the touch pad sensitivity to action buttons may help to mitigate this issue.

5.8 Information Display

As mentioned earlier, the OCU used for the GoldenEye-50 demonstration is an engineering prototype designed and used by engineers who likely have a background in flight sciences or aerodynamics and who fly the UAV in a non-operational environment. The OCU displays

information that, when translated properly from numbers to a mental image, can tell the operator what the UAV looks like in flight and whether it is engaged in safe flight. The personnel who will fly UAVs for the Army may not have (and may not be required to have) a background in flight sciences, so the need to translate numbers such as pitch, roll, and yaw angles would likely increase operator workload and error frequency. OCU display information should be such that it requires the least amount of calculation on behalf of the Soldier and minimizes the need for knowledge of flight sciences.

Table 2 summarizes the observations and recommendations for future analysis and design.

Table 2. Summary of observations and recommendations

Observation	Recommendation
The UAV demonstrated a lack of feedback on diagnostics and safe flight parameters.	The OCU should provide feedback and warnings to the operator as necessary. Scope of feedback and warnings requires further analysis.
The UAV operator repeatedly referenced certain information during flight missions.	The OCU interface design and layout of data displays and menu organization should consider the information most frequently accessed by the UAV operator.
The UAV operator used map zoom extensively.	The OCU interface design should consider the functions and features that OCU operators use most frequently and should support efficient use.
The UAV operator's primary task throughout all phases of flight missions was to monitor all real-time data read-outs for safe flight operations.	The OCU interface design should consider the task of monitoring information; displays should be designed to facilitate effective monitoring to include warnings and alerts.
Logistics and workload required three people to fly the UAV: ground crew member, UAV operator, payload operator.	The OCU interface design should reduce logistical burden and workload in order to minimize the number of personnel required to operate a UAV.
The UAV team performed multiple start-up checklists.	The OCU functionality should include electronic checklists to assist the operator in preparedness for UAV flight missions.
The UAV operator was only able to fly the aircraft in hover mode; the ability to observe transitioning between flight modes (from hover to wing borne) was not possible since the OCU interface was not designed for operation with multiple flight modes.	Assessment of the OCU interface design is needed to successfully accommodate multiple flight modes of a UAV.
The touch screen interface of the OCU was vulnerable to accidental input from the operator.	The OCU interface design should reduce the likelihood of accidental input through desensitization of the touch pad, keys and buttons, addition of a physical barrier or some other means.